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51

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GREENHOUSE EFFECT

DOE's Programs and Activities Relevant to the Global Warming Phenomenon

GAO/RCED-90-74BR

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Resources, Community, and
Economic Development Division

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The Honorable Mike Synar
Chairman, Subcommittee on Environment,
Energy and Natural Resources
Committee on Government Operations
House of Representatives

Dear Mr. Chairman:

This briefing report responds to your letter of October 20, 1988, requesting us to identify Department of Energy (DOE) programs and activities associated with global warming and DOE efforts to incorporate this issue into its energy policy and planning activities. Concerns about global warming stem from mounting scientific evidence that increasing concentrations of carbon dioxide and other trace gases generated by human activity are beginning to alter the heat balance of the earth's atmosphere.

You specifically requested information on (1) the scientific understanding of the global warming phenomenon and DOE's research efforts to fill information gaps on the issue, (2) the nature of program planning and criteria used by DOE for evaluating global warming research and development, (3) leadership in DOE on the global warming issue and efforts to integrate its various activities into energy policy and planning considerations, and (4) proposed policy and/or program changes made by responsible agencies or groups for improving energy efficiency and/or reducing energy-related emissions with potential climate change effects.

This report contains information orally presented to your office. In summary, we found the following:

- While considerable understanding of global climate systems has been gained in the past few years, major sources of uncertainty remain, including the role played by factors such as cloud cover, oceans, and vegetation growth. To help fill these information gaps, DOE undertakes direct research and collects data needed for carbon and climate system models used to predict potential climate changes. These direct research and development efforts represent a requested $28 million in fiscal year 1990 funds, an increase of about $5 million over fiscal year 1989 funding.
- DOE also conducts a wide range of other research development and demonstration programs it considers indirectly related to the global warming

issue, including efforts to increase energy efficiencies, promote conservation, and develop non-fossil energy technologies. For fiscal year 1990, DOE requested about $1.3 billion for these program areas, about $330 million more than the fiscal year 1989 funding level. In these program areas DOE has not established any written criteria or guidance to give special priority to projects on the basis of their relevance or potential impact on global climate change. Senior DOE officials stated that management considers the issue when making funding decisions.

- In July 1989, the Secretary of Energy established six principles that will form DOE's approach to the global climate change issue, and stated that the issue will be a central part of DOE's efforts to develop a new National Energy Strategy. In addition, several management initiatives have been taken that were related to the issue. These efforts have included compiling an inventory of DOE programs relevant to the issue, organizing a global warming conference, and establishing a DOE Climate Issue Response Group.
- Public and private organizations, including the Environmental Protection Agency and the World Resources Institute, have made many proposals to address global warming. Generally, the proposals suggested increasing energy efficiency, and switching from fossil fuel to non-fossil fuel based technologies, and/or reducing the emissions from fossil-fuel use.

Section 1 contains background information on the global warming issue and our objectives, scope, and methodology. Section 2 provides details on DOE policies and research efforts, while section 3 provides examples of energy policy and program changes to mitigate the global warming phenomenon that have been suggested by various federal and non-federal authorities.

Although this report, as you requested, is limited to a discussion of DOE's programs, we expect to issue two reports early in calendar year 1990 that will provide a more expansive discussion of the federal government's efforts on the global warming issue. These reports are (1) Global Warming: Further Research Will Reduce Scientific Uncertainties (GAO/RCED-90-58) and (2) Global Warming: Administration Approach Cautious Pending Validation of Threat (GAO/NSIAD-90-63).

To respond to your request, we interviewed senior DOE officials and managers responsible for programs and activities relevant to the global warming issue. We also reviewed (1) pertinent program documents and budget requests for each DOE program area, (2) proposed legislation and

congressional hearings, (3) various federal and non-federal reports and studies, and (4) numerous articles from various scientific and environmental journals. We did not evaluate whether individual DOE projects that the department considered relevant to global climate change were so, nor assess the relative funding priority given to individual programs or projects. We discussed the contents of a draft of this report with representatives of the Deputy Under Secretary; however, as agreed with your office, we did not obtain official written comments on this report.

As also arranged with your office, unless you publicly announce its contents earlier, we will make no further distribution of the report until 30 days from the date of this letter. At that time, we will send copies to the appropriate House and Senate committees, the Secretary of Energy, and the Director, Office of Management and Budget. Copies will also be made available to others upon request.

Should you have questions or need additional information, please contact me at (202) 275-1441. Major contributors to this report are included in appendix III.

Sincerely yours,

Victor S. Rezendes
Director, Energy Issues

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Abbreviations

CIRG	Climate Response Group
CES	Committee on Earth Sciences
CO_2	carbon dioxide
CFC	chlorofluorocarbon
CRS	Congressional Research Service
DOE	Department of Energy
EPRI	Electric Power Research Institute
EPA	Environmental Protection Agency
ES&H	Office of Environment, Safety and Health
IPCC	Intergovernmental Panel on Climate Change
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NO_x	nitrogen oxides
OSTP	Office of Science and Technology Policy
OTA	Office of Technology Assessment
USGS	U.S. Geological Survey
WRI	World Resources Institute

Introduction

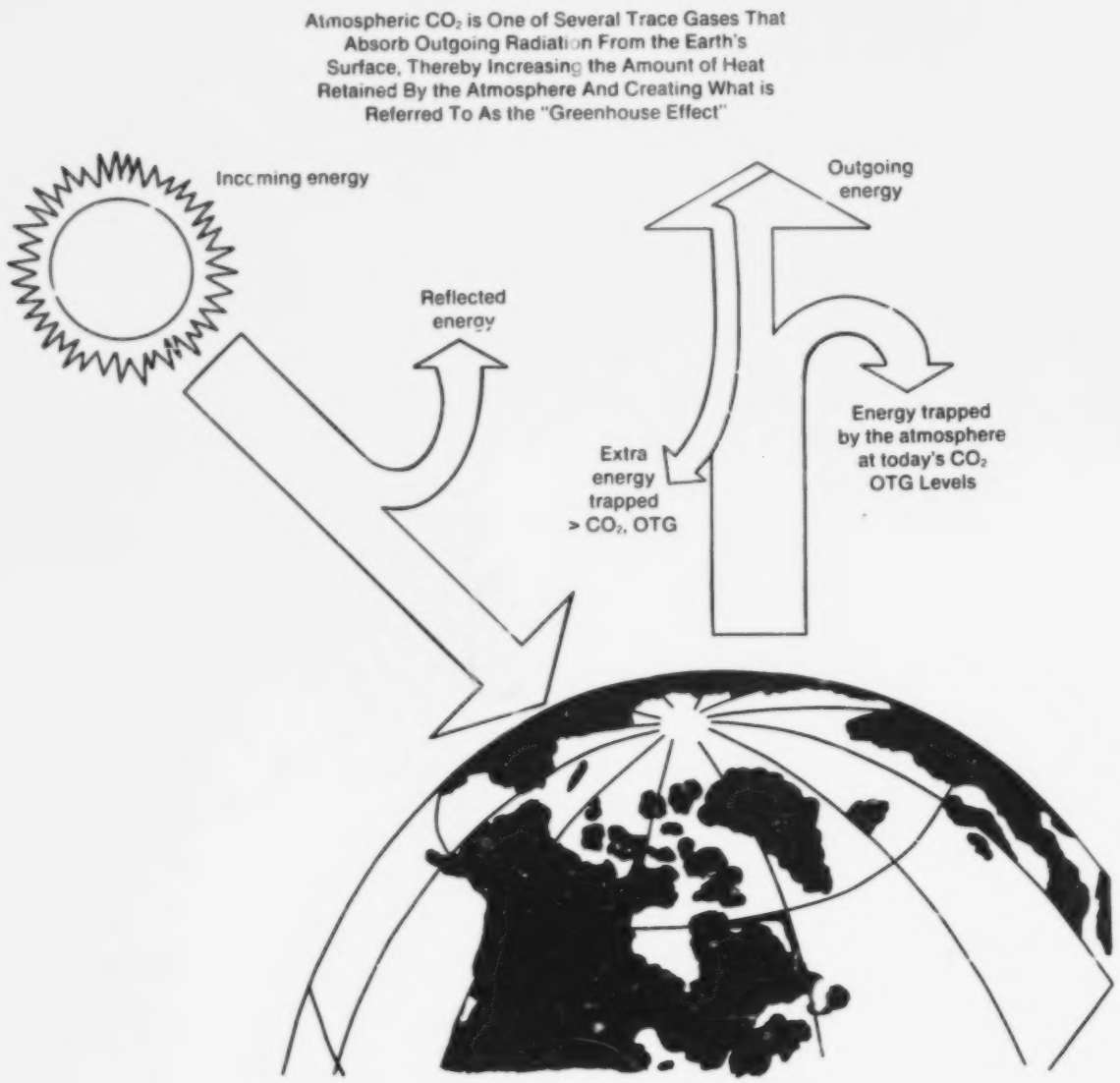
Concern about global warming stems from increased concentrations of carbon dioxide (CO_2) and other gaseous emissions generated from fossil-based energy production and use, and the belief that these increases are contributing to a steady increase in atmospheric and surface temperatures—the so-called "greenhouse effect." According to authorities, including DOE scientists, rising temperatures will cause changes in global climate and earth systems, significantly affecting human society and institutions.

Not surprisingly, the greenhouse effect and its energy-related implications have generated considerable political and public attention in the United States and many other industrialized nations. In the United States, DOE is one of several federal agencies engaged in atmospheric and climate research and is the major agency responsible for researching and encouraging developments in energy-production and energy-use technologies.

What Is Global Warming?

Mounting scientific evidence suggests that increasing concentrations of carbon dioxide (CO_2) and certain other trace gases generated by human activity are beginning to alter the chemical heat balance of our atmosphere. This phenomenon traps heat in the earth's atmosphere that would otherwise be released into outer space, resulting in a gradual warming of the atmosphere. The process is shown visually in figure 1.1.

Figure 1.1: The Greenhouse Effect


Atmospheric CO_2 is One of Several Trace Gases That Absorb Outgoing Radiation From the Earth's Surface, Thereby Increasing the Amount of Heat Retained By the Atmosphere And Creating What is Referred To As the "Greenhouse Effect"
Incoming energy
Reflected energy
Outgoing energy
Energy trapped by the atmosphere at today's CO_2 OTG Levels
Extra energy trapped > CO_2, OTG
OTG = Other Trace Gases E. G., CH_4, O_3, CFC., Etc.

Source: DOE 1987 Annual Report to Congress, p. 164

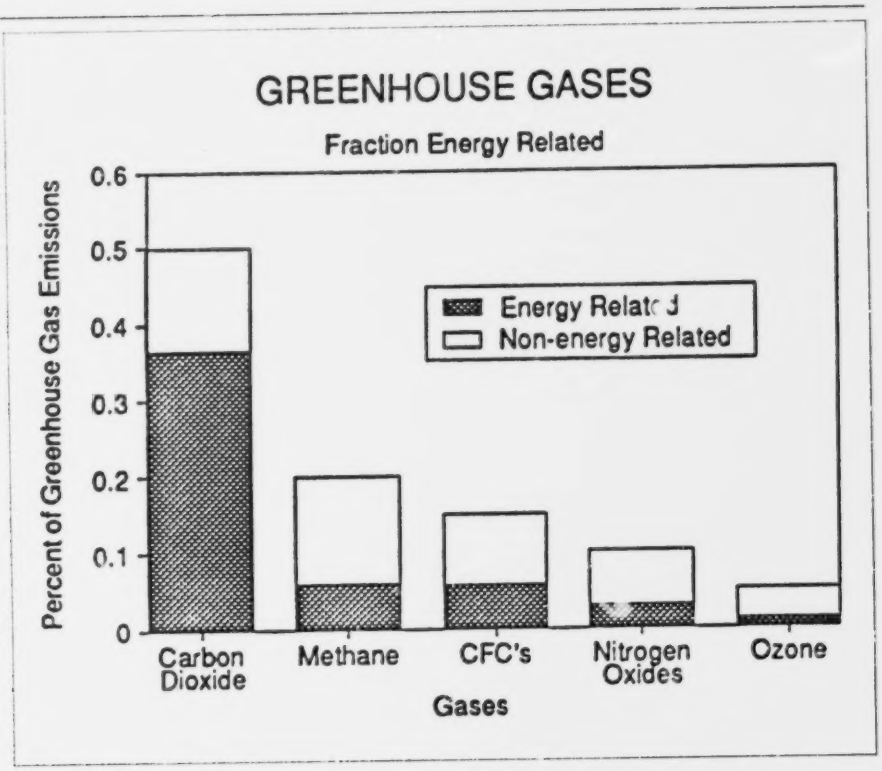
CO_2, which is essentially transparent to sunlight entering our atmosphere, absorbs or blocks some of the outgoing solar heat energy reflected from the earth's surface, as well as other heat energy generated by human and naturally occurring activities. An equilibrium between incoming and outgoing energy has maintained the relative stability of the earth's systems for thousands of years. DOE scientists and others have noted that with increasing concentrations of CO_2 entering the atmosphere, equilibrium is shifting so that more heat is being retained in the atmosphere than is being released into outer space.

According to DOE, atmospheric concentrations of CO_2 have increased approximately 25 percent from 1800 to 1985, mainly because of human influences—first from deforestation during massive global expansion of agriculture, and now primarily from fossil fuel burning. According to atmospheric scientists, current climate models suggest that the global average surface temperature will increase by some 2 to 6 degrees centigrade during the next century. These changes will in turn affect other earth systems including sea level, fisheries, agriculture, water resources, ecological systems, as well as human welfare.

While CO_2 is most frequently identified as the leading cause of the greenhouse effect, other trace gases are now estimated to be significant. Among these gases are nitrous oxide, methane (better known as natural gas), ozone, and chlorofluorocarbons (CFC's). According to current data, the buildup of these gases (with the exception of nitrous oxide) is occurring more rapidly than the rate of growth of CO_2. Further, because molecule for molecule these gases are more efficient absorbers of solar radiation than CO_2, it is believed that in the future they may become greater contributors to global warming than CO_2.

According to DOE, energy production and use account for about half of all the U.S. manmade gas emissions that produce climate change. The remainder arise from other sources, including agriculture, wetlands, and industrial products. Figure 1.2 shows the percentage relationship between energy-related greenhouse gases and non energy-related sources. As the figure shows, CO_2 is the most important of these gases in terms of total emissions, accounting for about 70 percent of the total energy-related climate change gases released.

Figure 1.2: Comparison of Energy-Related Greenhouse Gases to Non Energy-Related Gases



Source: Inventory of DOE Global Climate Change Programs, March 1989

Federal Programs and Activities

The federal government pursues a wide range of programs and activities relevant to the global climate-change issue through several agencies and special offices besides DOE. Among them are the National Science Foundation, National Oceanic and Atmospheric Administration (NOAA), Environmental Protection Agency (EPA), U.S. Department of Agriculture, National Aeronautics and Space Administration (NASA), and the U.S. Geological Survey (USGS).

Among other projects, the work of these agencies includes

- researching the basic and applied science questions about the relationships and changes in the atmospheric and earth systems;
- studying and assessing the array of potential or predicted environmental, ecological, societal, and economic impacts of climate change, and data gathering and assessing for policy analysis; and

- researching and developing innovations and new technologies of energy supply, production, and end-use that are being commonly recognized as the potential major contributors to both the near- and long-term solutions to meet future energy demand as well as reduce or eliminate greenhouse gas emissions.

For example, EPA's efforts focus on assessing and evaluating the ecological, environmental and health related consequences of global change, which reflects its regulatory mission. In addition, EPA has also been involved in efforts to develop policy options for stabilizing and reducing greenhouse gas emissions. NASA focuses on earth sciences research from space, including broad scientific studies of the planet as an integrated system. The Department of Commerce, through NOAA focuses on its mission-directed activities, including research on the physical and chemical processes in the climate system, climate modeling, and diagnostic techniques for detecting global changes.

Of special significance during the past 2 years has been the increased attention given to federal research initiatives overseen by the White House Office of Science and Technology Policy (OSTP) and its Federal Coordinating Council for Science, Engineering and Technology. In April 1987, the Director, OSTP, announced the establishment of the Committee on Earth Sciences (CES) specifically to coordinate federal research on earth sciences, identify policy and international issues, and conduct an array of activities designed to improve the effectiveness of federal research and development efforts. CES is composed of officials and experts in the various earth sciences and other disciplines from seven federal departments, including DOE.

In a major initiative, CES has been coordinating the current array of federal research programs that address the earth and atmospheric sciences and developing a framework to guide the planning and conduct of this work under what will now be referred to as the "U.S. Global Change Research Program." The resulting report, Our Changing Planet: A U.S. Strategy for Global Change Research, which accompanied the President's FY 1990 budget, provided the objectives and goals of the new program and summarized a research plan and implementation strategy for the United States. In July 1989, CES issued a more detailed and comprehensive research program plan.

International Attention to Global Climate Change

Since global climate change is an international issue, several international groups are involved in research efforts. A major effort now underway is the work of the Intergovernmental Panel on Climate Change (IPCC), established in 1987 by the World Meteorological Organization and the United Nations Environmental Program. Its basic tasks are to (1) assess the scientific information on the various components of the climate change, (2) assess the environmental and socioeconomic effects of climate change, and (3) formulate global-response strategies for managing the climate-change issue.

The IPCC established three working groups to address these tasks. United States representatives to the IPCC are members of Working Groups I and III. Working Group I is assessing available scientific information on climate change, and Working Group III is developing the international response strategies to climate change. Working Group II is assessing the environmental and socioeconomic impacts of climate change. DOE has played an important role in planning the U.S. position and approach. According to DOE managers, the IPCC initiatives are significant in establishing the international communication and cooperation needed to identify appropriate actions to address the issue.

Early in calendar year 1990, we expect to issue a report, Global Warming: Administration Approach Cautious Pending Validation of Threat (GAO/NSIAD-90-63), which will provide a broader discussion of federal leadership, coordination, and international cooperation on the global climate-change issue.

Objectives, Scope, and Methodology

In October 1988 the Chairman of the Subcommittee on Environment, Energy and Natural Resources, Committee on Government Operations, asked us to review the programs and activities of the Department of Energy (DOE) that address the global warming issue, and DOE's efforts to make the issue part of its energy policy and planning considerations. The request focused on several areas of interest about DOE programs, including

- the basic science understanding of the global warming phenomenon and areas where further research is needed to improve the scientific capability to predict, with appropriate assurance, potential climatic changes and the extent of global warming under various scenarios.
- program planning and criteria for global warming-related research and development initiatives.

- leadership in DOE on the global warming issue and DOE's effort to integrate the issue into its energy policy and planning considerations, and
- potential policy and program changes that would improve energy efficiency, and reduce energy-related CO_2 and other greenhouse gas emissions.

As agreed, we are providing information on DOE's programs and activities relevant to the global climate-change issue, as specified by the areas of concern contained in the Chairman's request letter. Accordingly, we did not evaluate how well DOE is pursuing its programs and activities that are considered relevant to the global climate-change issue.

To address the areas of interest, we interviewed senior DOE officials and program managers about their programs and activities relevant to the global climate-change issue. Among these were the Under Secretary, and selected Assistant and Deputy Assistant Secretaries of key organizational components of DOE, and other key program officials. However, we primarily reviewed numerous departmental and program-level documents, reports, and related materials on over 23 different program areas. We also obtained and reviewed a considerable number of reports, and related information from other federal agencies and private sector groups involved with the issue. Furthermore, we reviewed recent congressional hearings and bills introduced over the past two Congresses that were related to the issue.

To research information gaps in the basic science of the global warming phenomenon, we reviewed Office of Energy Research reports and related documents generated by the Carbon Dioxide Research Division, and interviewed key officials and program managers of this work. We supplemented this information with documentation from non-DOE sources involved in researching the scientific questions about the phenomenon.

To address the concern about program planning and criteria for funding projects that would affect the issue, we interviewed senior level DOE officials about the program and project selection process. We did not evaluate individual project selection decisions. To determine DOE leadership in the issue, we interviewed senior level officials, including the Under Secretary, and reviewed various departmental documents and related information.

To address the concerns about further efforts to improve energy efficiency, and reduce CO_2 and other greenhouse gases, we obtained documentation from DOE on its perspective of the global warming issue and how it should be addressed, and on its efforts to improve energy efficiency and reduce greenhouse gases. We supplemented this information by assembling the views of other experts and organizations on proposed energy-related options and strategies for addressing global warming.

As agreed, we did not obtain official agency comments on a draft of this briefing report; however, we did discuss its contents with representatives of the Office of the Deputy Under Secretary. Our work was conducted between December 1988 and July 1989.

DOE Policy and Programs Related to Global Warming

DOE pursues a range of energy science and technology research, development, and demonstration programs as well as assistance and information programs that are directly or indirectly related to global warming. Generally, DOE's policy is to emphasize increasing the understanding of basic scientific phenomena affecting global climate. Accordingly, DOE has increased its budget for direct research and taken several initiatives to improve management oversight and internal and external communication of its global warming activities.

DOE's programs indirectly related to global warming are aimed at increasing energy efficiency, developing non-fossil fuel based technologies, and reducing the environmental impact of fossil fuels. DOE advocates continuing these programs for a variety of reasons, but has not altered its planning or budgeting criteria to emphasize relevance of the programs to global warming. DOE's proposed funding for these program areas for fiscal year 1990 is about $1.3 billion, an increase of about $330 million over the fiscal year 1989 budget levels.

DOE Policy on Global Warming

DOE has concluded that currently available information about the increase of carbon dioxide in the atmosphere is cause for serious concern even at the most optimistic end of the range of predicted impacts. However, because significant uncertainties remain in the scientific understanding of the phenomenon, DOE advocates an emphasis on research that is directly related to expanding the knowledge of CO_2 effects on earth's climatological and biological systems.

Direct Programs Aim at Improving Knowledge of Climate Systems

The Associate Under Secretary of Energy, in August 11, 1988, testimony before the Senate Committee on Energy and Natural Resources, stated that scientific uncertainties about global warming must be reduced before the Nation commits its economic future to drastic and potentially misplaced policy responses. She also noted that reducing the scientific uncertainties is crucial in building an international consensus on the need for action and its appropriate form. DOE has proposed increasing the budget for direct research from about $23 million in fiscal year 1989 to about $28 million in fiscal year 1990.

DOE's Carbon Dioxide Research Program has provided considerable understanding of the role of CO_2 on world climate change and global warming. According to DOE, however, significant uncertainties surround the understanding of the global climate and carbon system, and the naturally occurring feedback mechanisms that could reduce any warming

trend caused by CO_2. Cloud cover, the role of oceans as a reservoir for CO_2, and the implications of enhanced vegetation growth in reducing CO_2 are among these areas of uncertainty.

According to an Office of Energy Research official, various environmental models used to predict potential change have been unable to agree on the effects of CO_2 in specific geographical or regional areas. Until the credibility of these models is improved, it will be difficult to predict potential climate and temperature changes under various environmental scenarios. According to DOE's Director of Energy Research, about 10 more years of CO_2 and other greenhouse gas research may be needed.

Further information on government-wide environmental models and research needs on this issue can be found in our report, Global Warming: Further Research Will Reduce Scientific Uncertainties (GAO/RCED-90-58), which we expect to issue early in calendar year 1990.

Indirect Programs Address Energy Efficiency Improvements and the Advancement of All Energy Technologies

DOE's Under Secretary has stated that efforts to address global warming should continue to be directed at improvements to energy efficiency in all energy technologies and in advancing non-fossil technologies including those based on renewables, nuclear, or fusion energy. DOE research and development programs encompassing these topics were established for reasons other than global climate change, but by their nature may contribute to the potential decrease in greenhouse gas emissions. Total funding for these program areas was $957 million in fiscal year 1989. DOE has requested $1,287,000 million for fiscal year 1990. The largest increase in proposed funding was for the Clean Coal Technology program within the Office of Fossil Energy. DOE has requested $575 million, which is a 242 percent increase over the fiscal year 1989 funding level. DOE's funding request for its conservation and renewable program area and nuclear energy program area is reduced for fiscal year 1990.

DOE does not use funding criteria or other guidance to help plan, review, or approve technology research, development, and demonstration programs and activities considered relevant to the global warming issue. However, senior DOE officials advised us that while there is no established criteria or guidance for assessing the significance of projects, there is recognition of program and project relevance to the issue in management program planning sessions and in the internal budget review process.

As part of its program and budget-planning process, DOE obtains advice from outside advisory panels composed of experts on particular areas of energy research and technology development. Advice concerning the relevance of global warming to a proposed research or development project may come from these groups. For example, DOE advised us that, under its Clean Coal Technology program, it sought advice for developing global warming criteria for its May 1, 1989, demonstration program solicitation. While DOE did not develop specific global-warming criteria, its solicitation does offer credit to projects that will, in part, reduce emissions of greenhouse gases.

DOE's Program Areas Relevant to Global Climate Change

DOE management officially identified over 24 program areas it considered relevant to the global climate-change issue. These program areas represented about $1 billion of DOE's fiscal year 1989 appropriation. DOE categorized them as either directly or indirectly related to the global climate-change issue. Most of these program areas were administered by five of the major program office's, including DOE's offices of

- Energy Research,
- Environment, Safety, and Health,
- Conservation and Renewable Energy,
- Fossil Energy, and
- Nuclear Energy.

While the nature and extent of each office's involvement varies, each contributes significantly to DOE's collective efforts on global warming. In this regard, these program offices are addressing either

- research and data gathering to better understand basic science climate-change implications of CO_2 and other energy-generated gas emissions for the atmosphere and earth systems;
- research, development, and demonstration of energy production and end-use technologies that improve operating efficiencies and energy conservation;
- research and demonstration of development of new technologies that expand our energy options for the future and incorporate environmental concerns in their design; and
- special policy and issue analyses, and data assembly efforts contributing to the issue.

Table 2.1 shows the fiscal years 1989 budget and 1990 budget request for the major program areas identified by DOE as relevant to the global climate-change issues.

Table 2.1: DOE's Fiscal Years 1989 Budget and 1990 Budget Request for Direct and Indirect Programs Relevant to Global Climate Change by Major DOE Program Areas

Dollars in Thousands	FY 1989 budget	FY 1990 request
Direct Programs		
Energy Research	$20,200	$27,200
Environment, Safety and Health	2,700	1,100
Total	**$22,900**	**$28,300**
Indirect Programs		
Conservation and Renewables	$302,300	$198,600
Energy Research	45,500	47,900
Magnetic Fusion	350,700	349,200
Environment, Safety and Health	600	200
Nuclear	102,800	56,700
Fossil	154,800	59,100
Clean Coal Technology[a]	167,600	575,000
Total	**$956,700**	**$1,287,000**
Total direct and indirect	**$979,600**	**$1,315,000**

[a]Multi-year DOE cost for DOE/industry demonstration plants not included in total

Appendix I provides further information on the objectives and activities of these areas.

Management Initiatives Focus on Oversight and Coordination

DOE management has taken a number of initiatives over the past year to improve its oversight of the global climate-change issue and to improve the internal and external communication and coordination on the matter. These initiatives include developing principles to guide DOE efforts on global warming, publishing an inventory of DOE global climate-change programs, holding a global warming roundtable conference in November 1988, and establishing the DOE Climate Issue Response Group (CIRG) in January 1989.

Principles for Guiding DOE Efforts

On July 26, 1989, the Secretary of Energy advised the Senate Committee on Energy and Natural Resources in a prepared statement that he had established six principles that will form DOE's approach to global climate-change policy. These are (1) take aggressive action on those issues on which scientific consensus exists, (2) assess the state of the science

on issues where no scientific consensus exists, and identify areas for further inquiry, (3) where scientific uncertainty exists, move forward with those measures that make sense on other grounds, such as efficiency, (4) consider the costs and benefits of any response measures suggested, (5) link responses to scientific and technical information, and (6) determine how to evaluate and share technological responses with developing countries.

In addition, the Secretary also advised the Congress that he had initiated the development of a national energy strategy. The Secretary announced his intention to incorporate global climate change, as well as other environmental concerns in this effort, which is to result in a comprehensive plan to guide DOE activities.

Inventory of Global Climate Change Programs

In September 1988 DOE published "Inventory of DOE Programs Relevant to Global Climate Change, 1989-1990."[1] This document describes DOE programs determined to have some significant bearing on the emissions of gases related to climate change arising from the production and use of energy in the United States. The inventory identifies over 24 program areas of DOE that cut across several of its major organizational components. These areas represent a range of programs and activities involving basic energy and environmental science research, technological research development and demonstration of energy systems, innovations and processes, and various other data-gathering and information-exchange activities.

Soon after the department distributed the inventory for review, the Under Secretary established a process for reviewing and coordinating information related to environmental issues, with focus on the global warming issue. The Under Secretary pointed out that these issues will increase in both prominence and complexity and will require careful and thorough coordination of information to convey departmental views and positions.

Global Warming Roundtable Conference

On November 22, 1988, at the direction of the Under Secretary, a Global Warming Roundtable Conference was held at DOE headquarters in Washington, D.C. for senior DOE managers and other involved federal and nonfederal experts and interested parties. The workshop provided a day-

[1]The DOE Inventory was modified on several occasions through March 30, 1989, including its title and selected material on programs and funding levels.

long 4-panel session led by representatives from DOE and other experts. It focused on such topics as atmospheric composition, climate trends, climate projections, climate models, and the scientific uncertainties of climate change.

While the workshop assembled no report or document disseminating the information it presented, according to a representative of the Office of Policy, Planning and Analysis, the Conference provided an effective forum for the presentation and discussion of views on the issue for those attending the workshop.

DOE Climate Issue Response Group

On January 18, 1989, the Under Secretary established a DOE task force designated as the Climate Issue Response Group (CIRG). The CIRG was instructed to examine a number of key issues facing DOE on the global climate-change issue and report to the Under Secretary on its findings. CIRG was directed to determine whether new policies and/or programs are needed for DOE to play an active long-term role in responding to the concerns over the possibility of global climate change.

CIRG issued a report on March 19, 1989, concluding that DOE should become proactive on the climate-change issue. Noting that DOE has never effectively balanced energy and environmental issues, the report stated that a single DOE official will be needed to be responsive to the increasing demands that global climate change will place on DOE in the future.

Suggested Changes to Energy Policies and Programs to Address Global Warming by Other Federal and Non-Federal Organizations and Individual Authorities

In addition to DOE's views on how the global climate-change issue should be addressed are the numerous views of other federal, non-federal, and international groups and individual experts. Collectively, the proposals address a wide-range of potential energy-related strategies and options directed at production, and end-use technologies, many of which are not unlike the direction offered by DOE. Numerous proposals have placed emphasis on maximizing the efficiencies of all energy technologies, especially fossil technology, and on employing various conservation measures and technologies to help reduce energy demand and reduce CO_2 and other harmful emissions. Further research and advancement of the non-fossil technologies, including renewables (i.e., solar, wind, geothermal, and hydroelectric) and the nuclear option are also among the major proposals for addressing the issue, along with advancing research on fusion energy and other major advances in energy production and transmission, including superconductivity research and application.

Among the federal providers of information on potential strategies and options have been the Office of Technology Assessment (OTA), Congressional Research Service (CRS), EPA, National Academy of Sciences (NAS), NOAA, National Aeronautics and Space Administration (NASA), as well as others. Among the non-federal contributors to the issue that have been involved with earth sciences, the environment, and energy technologies are such groups as the World Resources Institute (WRI), Electric Power Research Institute (EPRI), Environmental Defense Fund, American Council for an Energy Efficient Economy, American Nuclear Society, and many others, most of which have provided their perspectives in congressional hearings over the past year or two.

The following provides a brief representation of the types of energy-related strategies and options that have been offered by EPA, OTA, and the World Resources Institute to address global warming. The examples cited are not intended to capture the full range of areas for change but do provide a reflection of scope and complexity of some proposals and their implications for national economies.

Policy Options Proposed by Draft EPA Report

EPA has prepared its draft report, "Policy Options for Stabilizing Global Climate." The draft report prepared for the Congress addresses policy options that, if implemented, would stabilize current levels of atmospheric greenhouse gas concentrations. It also addresses the need for, and the implications of: significant changes to energy policy, including energy efficiency and development of alternatives to fossil fuels; reductions in the use of CFCs; ways to reduce other greenhouse gases; and the

potential for and effects of reducing deforestation and increasing reforestation.

The EPA study team noted that any policy options must be evaluated in the context of expected economic and technological developments, and in the context of uncertain effects that greenhouse gas emissions will have on the rate and magnitude of climate changes. To address these considerations the EPA team established four goals for the study. These goals were to

- assemble data on global trends in emissions and concentrations of all major greenhouse gases and activities that affect these gases;
- develop an integrated analytical framework to study how different assumptions about the global economy and the climate system could influence future greenhouse gas concentrations and global temperature;
- identify promising technologies and practices that could limit greenhouse gas emissions; and
- identify policy options that could influence future greenhouse gas concentrations and global warming.

The draft report defines a wide range of policy choices that could be considered to stabilize climate change. Proper pricing of energy services, according to the draft, may be the most important. It is critical to encourage both increases and end-use efficiency and the development of energy sources that emit no CO_2. Current market prices of fossil fuel do not reflect the risk of climate change and provide no incentive to consider the climate implications in purchase and investment decisions. A direct means of providing this incentive is a fee on fossil fuel in proportion to its relative impact on global warming. Regulatory programs could be used to complement the pricing strategies when they are ineffective, either because of market failures or inequitable impacts on some regions or income groups. The draft also stated that directing research and development priorities toward energy sources that produce no CO_2 is essential to assure the availability of attractive options over the long term. Other options include the selective use of government procurement to stimulate markets and promote technological alternatives as well as technical assistance and information programs.

It further stated in regard to energy policy options that no single policy approach by itself is likely to be both effective and acceptable as a means of achieving substantial reductions in greenhouse gas emissions from energy production and use. It noted that strategies for developing countries may be quite different from those appropriate for the United

States. However, it also stated that many complementary options exist that offer differing relative advantages for reducing greenhouse gas emissions.

Office of Technology Assessment

OTA has also provided its views on federal government action to limit global climate change. On June 29, 1988, Dr. Peter Blair of OTA's Energy and Materials Program provided his recommendations in testimony before the House Subcommittee on Natural Resources, Agriculture Research and the Environment and the Subcommittee on Science, Research, and Technology. He supported CO_2 reduction strategies that include reducing fossil fuel consumption through increasing end-use energy efficiency and alternative energy use, and shifting from high CO_2 emitting fuels like coal to those with relatively lower emissions like natural gas. To successfully carry out these strategies, OTA suggests using research and development measures and efficiency regulations.

Research, development, and marketing support for any resulting technologies has also been recommended by Dr. Blair as a means to improve the availability of alternative and energy-efficient technologies. Dr. Blair stressed that the federal presence in research, development, and demonstration is necessary to sustain conservation and renewable energy technology development in the United States since current low oil prices have essentially halted privately financed work. Besides, Dr. Blair notes one cannot expect private industry to fund the development of liquid fuel substitutes or new methods of generating electricity that are in line with environmental or national security concerns. But the government can encourage private industry participation in energy research by portraying it as a means of improving U.S. competitiveness in world markets.

Renewable and energy-efficiency combustion technologies may provide new markets for private industry to focus on, as well as encourage industry to rapidly turn over capital in order to maintain high productivity. Dr. Blair noted, for instance, the importance of reducing production costs and improving performance of renewable technologies to make them competitive with traditional energy sources. Dr. Blair also referenced combustion technologies like integrated gasification combined cycle generators, fluidized bed combustors, and compressed air energy storage facilities that may offer the potential for widespread use in electric power generating applications beyond the turn of the century. Thus, according to Dr. Blair, commercial acceptance of these technologies hinges on their being successfully demonstrated. Also, he noted that

OTA has found that demonstration programs are successful when a wide range of private sector interests participates heavily and is assured of technology proprietary rights and ownership. Cost-sharing between industry and a federal government committed to funding demonstrations is needed; such cost-shared demonstrations would prove the conceptual designs for new technologies as well as demonstrate multiple commercial applications for relatively mature technologies.

In addition to funding new technology research on electricity generation and energy-efficiency, Dr. Blair stated that the OTA feels the U.S. government should also help expand private sector commercialization opportunities by helping firms market their products in the U.S. Additionally, the federal government should help domestic companies establish access to foreign markets for new generating technology since the domestic market seems to be weak. Such efforts, which would be very important to these technologies' near-term viability, could include government loan guarantees, assistance with joint-venture and licensing applications in foreign countries, and aid in the formation of trading companies that export renewable energy technology.

Dr. Blair also stated that the government should promote the adoption of new technologies through regulations that set energy efficiency-related performance standards and product labeling.

World Resources Institute

On June 29, 1988, Dr. Jessica Mathews, of WRI provided her views on the issue of global climate change before the House Committee on Science, Space, and Technology. She stated that the best government policy is a policy of doing no harm, especially since we do not know the lag time between the emission of greenhouse gases and the establishment of the earth's new equilibrium climate. She noted that select policy initiatives can be matched to the level of certainty. She recommends increased policy research so that we know more about the possible options we have, such as global carbon taxes and joint activities to improve efficiency. She also believes the U.S. should reexamine its research and development priorities, and emphasize long-term research, especially on non-fossil alternatives. Beyond emphasizing policy and research, Dr. Mathews specifically would like the U.S. to provide international leadership on global climate issues, such as completing phasing-out CFC's and limiting tropical deforestation. She also recommends promoting energy efficiency by organizing a national energy plan built around the development of highly efficient processes, appliances, and automobiles. Dr. Mathews feels energy-efficiency improvements are the most attractive

and cost-effective ways to reduce greenhouse gas emissions. Such national policies could, according to Dr. Mathews, promote switching to less-carbon fuels, like renewables and the relatively clean-burning natural gas, which can be used with new, higher efficiency gas-fired and steam-injected turbines.

Dr. Irving Mintzer, also of WRI, expanded on Dr. Mathews' suggestions to increase energy efficiency, switch to less carbon-intensive fuels, and develop renewable technologies. Dr. Mintzer's, September 22, 1988, statement for the House Subcommittee on Energy and Power, Committee on Energy and Commerce, noted that policy choices made today and implemented over the next several decades can substantially affect the timing and extent of global warming.

Dr. Mintzer stated that the most important energy policy options for reducing the rate of global warming include

- increasing the efficiency of energy use through technical improvements and through changes in pricing policy to eliminate subsidies,
- fuel-switching to less carbon-intensive fuels and the development of renewable technologies, and
- reducing the use of the most dangerous CFCs.

In this regard, he noted that there are a wide range of cost effective measures available today to reduce the United States' contribution to future global warming. He organized these measures into three categories

- getting the prices of energy and fuels right,
- reducing greenhouse gases at the sources, and
- offsetting future emissions to reduce their effect.

The specific measures cited by Dr. Mintzer included

- introducing a tax on gasoline starting at 2 cents per gallon and increasing 2 cents per gallon per month for 4 years,
- instituting a carbon tax on all fossil fuels made revenue-neutral through tax credits for investments in energy efficiency,
- demonstrating in all federal buildings those energy efficiency measures certified cost-effective by the Secretary of Energy, and
- demonstrating through joint public-private ventures some of the new high-efficiency electric supply technologies.

Dr. Mintzer believes that implementing these and other specific measures could postpone for as much as 60 years the global commitment to a warming equal to the effect of doubling the pre-industrial concentrations of CO_2 alone.

To provide some additional examples of the various suggestions being offered, appendix II includes information offered by the EPRI, the World Climate Program Workshop of 1987, the American Nuclear Society, the National Academy of Engineering, the American Council for an Energy-Efficient Economy, the Environmental Defense Fund, and the Lawrence Livermore National Laboratory on fusion energy.

Descriptions of DOE Program Areas Relevant to the Global Climate-Change Issue

As noted in section II, of the 24 program areas identified by DOE as relevant to the global climate-change issue, only 2 areas were considered directly related to the issue. These areas included the Carbon Dioxide Research Program of its Office of Energy Research, and several environmental studies and special assessments being conducted by its Office of Environment, Safety and Health. The majority of the program areas DOE identified were judged to be indirectly relevant to the issue.

The following provides some description of the offices and program areas DOE identified.

Direct Programs

Office of Energy Research

DOE's Office of Energy Research supports and coordinates a wide range of basic and applied research activities. The Carbon Dioxide Research Program, within its Office of Health and Environmental Research, directly contributes to the further understanding of the climate-change issue.

Carbon Dioxide Research Program

The Carbon Dioxide Research Program, initiated in 1978, is directly related to DOE's global warming issue and has over the past 10 years provided much of what the U.S. and international community currently know about CO_2 and its relationship to global climate change. The program's objective is to develop the scientific knowledge base for policy formulation and government action in response to changes in atmospheric CO_2 and its primary effects on the earth's climate and biological systems.

According to the CO_2 program managers, achievement of this goal requires increased understanding of CO_2 implications for the global atmosphere, plant and animal life, oceans, and the ice and snow covered portions of the earth. In this regard, research supported by the program is directed toward reducing the scientific uncertainties about CO_2 and producing estimates of CO_2-induced climate change. According to the Office of Energy Research, with a comprehensive understanding of carbon dioxide-induced changes, it should be in a position to help formulate options and strategies by which we can modify or adapt to these potential atmospheric and earth systems changes, and analyze them with regard to risk and cost benefit. As noted in section II of this report, the work of the CO_2 Research Program has provided much of the basis for

the department's position on the global warming phenomenon and the strategy that it believes should be pursued to address the issue.

Because of the diverse types of research needed to meet broad objectives of the program, a wide range of institutions is involved in this work. These institutions include the academic community, the DOE national laboratories, private sector research organizations, and other government agencies. The program has been organized into six work areas including energy systems, climate systems, vegetation research, resource analysis, scientific interface, and institutional and international activities. The energy systems research area covers research in energy technology, energy emissions, and the carbon cycle. The goal of this program area is to forecast future concentrations of CO_2 in the atmosphere. Its more specific objectives are to (1) reduce the uncertainties about the various parts of the carbon cycle, (2) develop the capability to project energy emissions of CO_2, (3) identify technological developments that could reduce CO_2 emissions, and (4) develop suitable models for projecting atmospheric con centrations of CO_2.

The climate system program area focuses on the physical environment to which man and the biosphere respond. The primary objective of this work is to develop and improve the capabilities to estimate the range of global and regional climate change resulting from increasing CO_2. Its second objective is to detect evidence of climate system response to past and continuing increase of CO_2, and its third objective is to provide information for resource analysis.

The focus of the vegetation systems research area is to provide information about the effects of CO_2 on climate vegetation systems. An important requirement of work in this area is to acquire new experimental data and to develop and validate models for improving predictions from altered CO_2 and climate conditions. Once developed and tested, models would be applied to different types of vegetation (e.g., forests, range lands) and at larger geographic scales.

The resource analysis program area focuses on the potential impacts of CO_2 and climate change on important resources including agriculture, forests, fisheries, and water resources. The primary objectives in this area are to provide integrated quantitative analysis of the effects of CO_2-induced climate change on key resources in order to develop useful responses to possible problems in this area, as well as to develop mechanisms to take advantage of benefits of CO_2-induced change.

The scientific interface area relates to efforts to communicate research results, and generate review and quality control analyses of work. This includes reporting, conferences, and access to data on research results. The institutional and international program area is focused on the need for institutional and international coordination and cooperation on the collective findings of the world research community.

Office of Environment, Safety and Health

The Office of Environment, Safety and Health (ES&H) has objectives of assuring that DOE policies and programs conform to all applicable environmental laws and regulations and incorporate national environmental protection goals into their plans. ES&H fulfills this objective by providing analyses and developing options regarding significant national environmental and energy issues.

ES&H's Office of Environmental Analysis analyzes policy options for multi-national energy and environmental concerns such as global climate change and stratospheric ozone protection, in addition to domestic issues like national supply, demand, and prices of energy.

Current activities identified as directly related to the global warming issue are four congressionally mandated studies that are addressing several key aspects of the issue. These include

- an assessment of research and development of alternative energy sources; and development of appropriate research and development strategies, including additional federal investment to encourage greater private investment in these alternative energy sources;
- an inventory and policy study to identify the sources of CO_2 in the U.S. and policy options that would lead to designated reductions in U.S. CO_2 emissions;
- a study of data on greenhouse gases that will identify sources and trends of emissions and impacts on climate change and that will also identify federal data sources and the use and coordination of data; and
- a study of policy options to mobilize the private sector's cooperation in mitigating, adapting, and preventing global climate change.

In February 1989 the Office of Environmental Analysis prepared the Project Plan for Congressionally Mandated Studies on Energy and Climate Change Policy Issues (Project Plan) that set out the objectives, approaches, and timetables for these studies.

Indirect Programs

Of the 24 program areas identified by DOE as related to the global warming issue, 22 areas were considered indirectly related. These 22 program areas are administered by 5 DOE offices.

Office of Conservation and Renewable Energy Programs

The Office of Conservation and Renewable Energy conducts a range of programs that form a major part of DOE efforts considered to be indirectly relevant to the global climate-change issue. The primary purpose of this office is to help develop, assist, and encourage the application of technologies that enhance the efficiency of energy use and provide flexibility in the choice of energy alternatives as well as to develop renewable energy sources.

According to the Assistant Secretary for Conservation and Renewable Energy, the advancement of energy efficiency technologies, conservation measures, and renewable technologies can have a significant impact on the demand for fossil fuels and can reduce CO_2 and other greenhouse gas emissions. When discussing the conservation and renewable programs of DOE before the House Committee on Energy and Commerce, on September 22, 1988, the Under Secretary noted that conservation programs that aim to develop new technologies for using energy more efficiently affect all end-use energy sectors and that improvements in end-use efficiencies could reduce the growth in future energy demand as much as 16 quads[1] annually by the year 2010. In this regard, such improvements can help slow the rate of growth in the use of fossil fuels and provide the time needed to develop and commercialize alternative energy supply options. She also noted that DOE is pursuing precisely this course of action.

Incentives to Improve Energy Efficiency

According to DOE, its work in the conservation and renewables area is to improve the efficiency and fuel flexibility of energy use in buildings, transportation, and industry. Its programs are to work in partnership with the private sector in order to advance new technologies to the point at which commercial development can proceed without further federal assistance. The Assistant Secretary for Conservation and Renewable Energy noted that many of their programs involve cost sharing, which is viewed as a major incentive to encourage participation of both the public and private sectors. As part of their programs and individual projects, numerous conferences, periodic workshops, and meetings with public and private sector representatives are held to discuss emerging technologies and ideas for energy efficiency improvements.

[1]A quad is a quadrillion British thermal units (Btu), the energy equivalent of more than $5 billion.

Office of Conservation

The Office of Conservation has a broad range of responsibilities focused on basic and applied research, and assistance programs designed, in part, to

- contribute to the development and application of technologies to improve energy efficiency, productivity, and environmental quality;
- provide engineering and scientific knowledge to the academic and private sectors, and stimulate technology transfer;
- encourage private sector participation in areas of energy research with substantial risk and unpredictable economic outcomes; and
- help to establish or maintain the U.S. leadership in key energy technology and its competitiveness in international commerce.

The Office of Conservation addresses these areas through its individual program offices including its Offices of Energy Utilization Research, Buildings and Community Systems, Industrial Programs, Transportation Systems, and Federal Energy Management Program.

The Office of Energy Utilization Research supports long-term research and development to advance energy end-use technologies. It does this through its Energy Conversion and Utilization Program and its Inventions and Innovations Program. The objectives of the Energy Conversion and Utilization Program are to increase the U.S. energy supply by developing alternative end-use energy technologies as well as by developing more efficient methods of energy use.

The Office of Buildings and Community Systems supports technologies that are transferable to the building design, construction, retrofit, and energy management industries in order to increase building energy efficiency. This office also promotes the development of energy efficiency standards and test procedures for major household appliances.

The Office of Industrial Program's objective is to improve the energy efficiency of industrial production by developing technologies that use alternative fuels. As the Office of Conservation believes U.S. industry is generally less energy-efficient than its foreign counterparts, it hopes that by the year 2010 the U.S. will reduce its industrial energy consumption by 13 percent through the development of new technologies.

The Office of Transportation System's objectives are to control or eliminate CFC losses from automobile air conditioners, to develop advanced engine technologies that could improve fuel efficiency by 30 percent, and to promote alternate transportation fuel use. These activities are

carried out through two research areas—Heat Engine Propulsion and Electric and Hybrid Propulsion. The Heat Engine Propulsion projects have two main goals. First, the projects aim to solve problems related to use of non-petroleum fuels so that synthetic fuels derived from oil shale and coal—and to a lesser extent from biomass and natural gas sources—can be utilized in motor vehicles. The projects also aim to develop advanced automotive engines. A promising program area is the development of ceramic components to replace certain metal ones currently found in engines. Conservative estimates state that ceramic components use could result in at least a 20-percent increase in fuel efficiency. Electric and Hybrid Propulsion projects support research and development to improve the range, reliability, cost, and performance of electric and hybrid vehicles.

The Federal Energy Management Program guides federal establishments in their management of energy. Its primary goals focus on improving efficiency and flexibility in energy use. Its ultimate aim is to reduce the energy used by the single largest energy consumer in the U.S., the federal government.

Office of Renewable Energy

The Office of Renewable Energy is responsible for planning, research and development, demonstration and evaluation of all forms of renewable energy. This includes pursuing long-term high risk research and development, and transferring renewable technologies to the public and private producers and consumers of energy.

Wind, solar energy, hydro, geothermal, biomass[2] and ocean resources are the basis for these technologies and, according to the Office, represent a vast source of potential energy. These technologies also offer viable, low environmental impact options for the U.S. and world community. According to the Deputy Assistant Secretary for Renewable Energy, all renewable technology options result in the reduction of greenhouse gas emissions and therefore have a direct positive effect on global warming, while representing the most environmentally benign of all energy supply options.

Today renewable energy technologies provide about 9 percent of the U.S. domestic energy production and are now estimated to reach about 13 to 15 percent by the year 2010. According to the Office of Renewable Energy, expanding the use of these technologies beyond their current

[2]Biomass is dry organic matter, i.e., plant materials and animal waste, used as a source of fuel.

applications and markets depends on research. The Office of Renewable Energy believes the preferred approach to achieving the potential for renewable energy technologies is through a realistic, far-sighted effort to improve the technology base via research in critical areas of system cost reduction, improved performance, and extended operating lives. By conducting such research now, renewable technologies will be better positioned to widely contribute to future energy and environmental requirements.

The renewable energy technologies are pursued by several program offices including the Office of Renewable Energy Technologies, the Office of Solar Heat Technologies, the Office of Solar Electric Technologies, and the Office of Energy Storage and Distribution. The following provides brief descriptions of the projects and activities of these offices.

The Office of Renewable Energy Technologies emphasizes both the development of biomass and other energy production and conversion technologies, and the expanded utilization of various geothermal resources. This work is conducted through the Office of Biofuels and Municipal Waste Technology and the Office of Geothermal Technology.

The Office of Biofuels and Municipal Waste Technology focuses its research predominantly on the raw materials used in the formation of liquid and gaseous fuels from biomass sources. Its projects are designed to increase the productivity, lower the cultivation costs, and improve the conversion characteristics of aquatic and terrestrial energy plants. These projects aim to increase utilization of biomass resources, which are the only renewable ones capable of directly producing gasoline, diesel, and natural gas fuels. Biomass now supplies 3 quads of energy in the U.S.: 2.8 of this total is provided by wood combustion; the remainder comes from municipal solid waste utilization.

The Office of Geothermal Technology would expand the use of geothermal energy beyond that of the high-temperature hydrothermal steam fields that currently produce competitively priced electricity. The office aims to produce electricity from liquid-dominated, moderate-temperature resources, as well as from hot dry rock and molten material.

The Office of Solar Heat Technologies aims to develop commercially-competitive solar alternatives for the heating, cooling, and lighting of buildings. Its goal is to make environmentally benign solar thermal technologies commercially competitive by the late 1990s. Working to achieve

these goals are the Offices of Solar Building Technologies and Solar Thermal Technologies.

Specifically, the Office of Solar Buildings Technologies conducts research to develop advanced materials and systems appropriate for collecting, storing, managing, and distributing solar energy in new and existing buildings. According to the Office of Renewable Energy, these developments could, in the future, supply up to 80 percent of building space heating and hot water requirements, 60 percent of residential cooling requirements, and up to 60 percent of nonresidential heating, cooling, and daylighting energy requirements at competitive costs. The purpose of the Solar Thermal Program is to improve solar thermal-systems performance and provide cost-effective energy options by the late 1990s that are strategically secure and environmentally benign.

The Office of Solar Electric Technologies pursues the development of wind energy and photovoltaic systems that will generate electricity and make it commercially applicable all over the U.S. It is also pursuing the development of ocean thermal energy conversion to a point at which its commercial potential as a power supply option can be assessed. This work is undertaken by its Office of Wind and Ocean Technologies, and the Office of Photovoltaic Technology.

The Office of Wind and Ocean Technologies emphasizes research to improve airfoils, blade materials, turbine/components and standardized designs. According to the Office of Renewable Energy, lighter turbine components that can withstand the stress caused by gravity, centrifugal forces, and wind turbulence, and that have an acceptable life cycle make the wind energy option competitive with fossil fuel combustion. According to this Office, advances in wind energy technology have reduced generation costs from 10 to 15 cents/kWh in the early 1980s to today's 7 to 8 cents/kWh. One reason for increasing wind utilization is that this energy option does not produce any greenhouse gas emissions and has, through its generation of 3.9 billion kWh of electricity in the past 8 years, resulted in 3 million tons less of CO_2-emissions than coal would have produced. The Office of Wind and Ocean Technologies also pursues ocean thermal technology, which takes advantage of the temperature differences between ocean surface and deep cold water from which energy can be extracted to generate electricity.

The Office of Photovoltaic Technology aims to further assist in the development of photovoltaic technology for large-scale generation of economically competitive electric power so that photovoltaic energy

products can be a significant partner in the mix of energy sources. This office seeks to improve the efficiency of photovoltaic systems by 15 to 25 percent, reduce production costs by 80 percent, and increase system lifetimes to 30 years.

The Office of Energy Storage and Distribution focuses on research programs in energy storage control and delivery. This office promotes research and development designed to reduce energy transmission and distribution losses in order to improve the efficiency of these delivery processes. Some of the Office of Energy Storage and Distribution's more important programs include development of advanced battery, thermal energy storage, and superconductivity electrical distribution systems.

Office of State and Local Programs

The Office of State and Local Assistance Programs within DOE's Office of Conservation and Renewable Energy aims to increase non-federal participation in energy projects and oversee programs funded by grants and oil overcharge payments through a number of activities. These activities are carried out through the Office's State Energy Conservation, Energy Extension Service, Institutional Conservation, and Weatherization Assistance Programs.

The State Energy Conservation Program's objective is to promote energy efficiency and reduce energy-demand growth in states. DOE provides grants and technical assistance to states for the development and implementation of approved comprehensive conservation plans; additionally, oil overcharge funds may be used to supplement State Energy Conservation programs.

The Energy Extension Service is a federal/state partnership established by the National Energy Extension Service Act of 1977 to provide small-scale energy users such as small businesses and individual homeowners with energy education and technical assistance that would facilitate energy efficiency, energy conservation, and the use of renewable resources. This state-facilitated program targets individual energy consumers and small businesses, who, unlike large industries that have an economic incentive to increase energy efficiency, are hampered by time and cost constraints in implementing the most effective energy-efficient technologies.

The Institutional Conservation Program aims to facilitate the implementation of energy conservation measures in the institutional sector by

funding matching, cost-shared grants for detailed building energy analyses and energy-saving capital improvements in nonprofit schools and hospitals. This program helps to solve the three most important institutional energy needs—financing, expertise, and information.

The Weatherization Assistance Program seeks to reduce the heating and cooling costs for those with low incomes, as well as the elderly, and handicapped. The program does this by providing grants to states and others to install weatherization materials in the homes of eligible recipients. In addition, it helps state and local program managers develop and implement those cost-effective weatherization measures, such as caulking and weatherstripping, storm windows, attic insulation, and heating system improvements, that are based on priorities established through energy audits.

Office of Fossil Energy

The Office of Fossil Energy has the broad objectives of increasing the efficiency of coal utilization and conversion, improving coal treatment processes that remove impurities, developing alternate fuels, and improving extraction techniques for natural gas, a relatively environmentally benign fossil fuel. This work is pursued by the Office of Coal Technology and the Office of Oil, Gas, Shale, and Special Technologies.

Office of Coal Technology

The Office of Coal Technology is pursuing the improved performance of coal by conducting advanced technology development for each of the major steps of the coal-use cycle: coal preparation, utilization, conversion, cleanup, and waste management. It has a primary mission to develop and demonstrate a slate of technologies that will extend the use of coal in power plants, factories, commercial businesses, residential complexes and transportation markets. These innovative technologies are designed to allow coal to be used cheaply, cleanly, and conveniently.

In this regard, the office is responsible for several programs, including the management of cooperative agreements with industry to foster clean coal technology; research and development programs for coal combustion and conversion embodying retrofit or near- or mid-term applications such as fluidized-bed combustion and surface coal gasification. It is also responsible for the environmental, health, and safety technology activities integral to such coal combustion and conversion systems. These programs and activities are accomplished by its Office of Coal Research and Development and its Office of Clean Coal.

The Coal R&D Program's goal is to strengthen the scientific and engineering technology base with which industry can develop new coal utilization products and processes. This program supports substantial activities in control technology, coal preparation, and combustion systems.

Within the Office of Clean Coal is administered the Clean Coal Technology Demonstration Program. In this program, DOE, in conjunction with private industry, is trying to demonstrate the commercial feasibility and environmental acceptability of technologies developed by the Office of Coal Technology's Coal Research and Development area. These demonstrations can result in the more efficient deployment of technologies that would reduce NO_x emissions associated with fossil fuel combustion. This work is carried out through clean coal technology and innovative clean coal technology demonstrations.

Office of Oil, Gas, Shale, and Special Technologies

This office conducts programs on special technologies, including such advanced coal-based technologies as programs on magnetohydrodynamics electric power generation and fuel cell systems. It is also responsible for the research addressing selected technologies for efficient and economical production of gas from unconventional sources.

The Magnetohydrodynamics Program pursues the development of commercially viable power generation systems which accelerate hot coal gases through an intense magnetic field to generate electricity. The Fuel Cells System Program supports the high-risk, high-payoff technological development of cost-effective, environmentally acceptable fuel cell systems which directly convert the hydrogen-rich gas derived from coal and dual (gas and coal) fuels into electricity. The Unconventional Gas Recovery Program's goal is to develop, with industry, environmentally acceptable advanced technologies for recovering gas from large, but currently uneconomical resources by the year 2000.

Office of Nuclear Energy

The Office of Nuclear Energy supports the National Energy Policy Plan of revitalizing nuclear energy through several programs, including its advanced Fission Reactor Development, Low-Level Nuclear Waste, and Uranium Enrichment programs. These programs would thus encourage increased nuclear energy utilization. According to DOE, nuclear energy is an important part of the U.S. energy mix, since it currently provides nearly 20 percent of U.S. electricity without directly generating CO_2. DOE estimates that about 200 million fewer tons of carbon are currently emitted annually due to use of nuclear-generated electricity.

Through the Advanced Fission Reactor Development Program DOE is focusing its efforts, along with industry's, on developing simplified reactor designs, passive safety features, certified standard designs by Nuclear Regulatory Commission, and on preparing them for commercialization and/or demonstration in the 1990s. The designs being developed are for advanced light-water reactors, liquid-metal reactors, and modular high-temperature gas-cooled reactors.

Office of International Affairs and Energy Emergencies

The Office of International Affairs and Energy Emergencies is responsible for developing and directing international energy policy, including the international component of overall energy policy, and for coordinating the department's energy emergency preparedness planning and emergency operations (except nuclear incidents/accidents). Activities considered related to the global climate-change issue are conducted by its Office of International Affairs.

The Office of International Affairs aims to develop a departmental international strategy that would deal with mitigation and adjustment policies. As global climate-change is an international issue requiring international communication and coordination, this office is actively involved in both bilateral and multilateral projects, and in special activities.

Office of Energy Research

The Office of Energy Research is also the organizational component in which the department's fusion research is managed through its Office of Fusion Energy. This program area is considered by DOE to be indirectly related to the climate-change issue. The goal of the Magnetic Fusion Program is to establish the scientific and technological base required for fusion energy. According to the Office of Fusion Energy, if successfully developed, fusion could provide the energy needed by the growing world population with minimal safety and environmental risks. This program is part of a coordinated world-fusion effort carried out under agreements with the European Community, Japan, and the Soviet Union.

In addition to the above major program offices is DOE's Office of Policy, Planning and Analysis. This office serves as a principal advisor to the Secretary of DOE on energy policy and carries out evaluations of DOE programs to assess their conformance with policy objectives. It also conducts various other specialized studies and assessment exercises and works with program offices on a number of projects. Such efforts

include a special least-cost utility study and a natural gas study. According to DOE, the least-cost utility study will develop new estimates of what can be achieved from demand-side management programs in public utilities, and will provide a framework for demand-side programs to reduce greenhouse gases. The natural gas initiative is to assess gas resource potential, demand potential, and various other gas markets and technologies. The primary purpose of this study is to identify impediments to and opportunities for displacing oil with gas in U.S. markets. The Office is also responsible for developing policy-related material for the Department on such issues as automobile fuel efficiency standards which the Secretary provides to the Department of Transportation when considering changes to these standards.

As previously noted, the Office of Policy, Planning and Analysis was also responsible for developing the Inventory of DOE Climate Change Programs, and arranged for DOE's Global Warming Round Table Conference. Most recently the Secretary announced that this office would be the department's focal point on the global climate-change issue, and that the head of the office would now be a Deputy Under Secretary position.

Additional Information on Suggested Energy Policy and Program Changes to Address Global Warming

Electric Power Research Institute

On November 15-16, 1988, Ian M. Torrens of EPRI provided his views on the global climate-change issue before the Conference on Global Climate Linkages: Acid Rain, Air Quality and Stratospheric Ozone. With regard to the calls for policymakers to react in some way to the issue, including the need to do more than continued research, Torrens pointed out that the

"challenge will be to achieve the correct balance between two broad policy thrusts: on the one side R&D which is clearly needed on both the complexities of the phenomena and the mitigation techniques; and on the other side an appropriate mix of the less costly and more effective actions to improve energy efficiency, and reduce emissions of the series of greenhouse and acid gases, which are not being taken at present for economic or institutional reasons. The answer is certainly not one or the other and finding out where to strike the appropriate balance will not be easy, in view of the scientific uncertainties."

To reduce CO_2 emissions from power generation, Torrens offered the following measures: (1) increasing the efficiency of primary generation with improved electronic and environmental control, heat recovery, and energy conversion systems; (2) implementing energy conservation schemes and improved end-use energy efficiency technologies; (3) shifting to high-hydrogen content, low CO_2- emitting fuels and non-fossil energy sources; and (4) removing CO_2 from power plant effluents with end-of-stack acid gas removal techniques.

To increase the generating efficiency of utilities, Torrens advocated the greater use of combined-cycle methods fueled with natural gas or gasified coal which produce electricity at about 45 percent and 38 percent efficiencies—as compared to 30 to 34 percent for conventional fossil fuel boiler systems—and which provide the additional environmental benefit of reduced sulfur dioxide and nitrous oxides. Torrens also advocated the use of clean coal technologies that improve the effectiveness of pollutant control, and of cogeneration technologies, which utilize waste heat.

To increase electricity end-use efficiency, Torrens recommended the development and application of energy-efficient electrical machinery in industry, improved electronic controls in heating and air conditioning use, and improved lighting efficiency. Torrens also believed utility demand-side planning and consumer conservation could help limit energy usage and its resultant greenhouse gas emissions.

Ian Torrens has also advocated shifting to non-fossil and hydrogen-rich fossil fuels emitting less CO_2 per unit of energy generated. A shift to

hydrogen-rich fuels would initially increase natural gas use that could continue for a few decades until U.S. gas reserves ran dry.

CO_2 scrubbing, or the recovery of CO_2 from power plant effluents, was also suggested by Torrens as a way to limit greenhouse gas emissions, even though the method's effectiveness and cost prohibit its utilization now. To reduce CO_2 emissions from the transportation sector, Torrens supported electric vehicle development. Torrens said that electric vehicles running on batteries charged by off-peak nuclear energy could result in decreased CO_2 emissions, if they replace combustion engines that have conversion efficiencies of less than 20 percent. Torrens noted, however, that comparison of data on electric vehicles versus gasoline driven vehicles points out that CO_2 emissions reduction would not be an argument for electric vehicles if the electricity for charging vehicle batteries were generated by coal-fired power plants.

World Climate Program Workshop of 1987

Suggestions for climate-change response policies were proposed by the World Climate Program Workshops that took place in Villach, Austria, and Bellagio, Italy, in the fall of 1987. These workshops discussed the technical, financial, and institutional options to address climate change in the near future. The workshops were organized by representatives from research organizations including the Bajer Institute, the Woods Hole Research Center, and the Environmental Defense Fund.

The report resulting from the workshop, "Developing Policies for Responding to Climatic Change," advocated further global climate monitoring and climate model development in order to reduce uncertainties about the biological and geochemical interactions that contribute to future environmental and socioeconomic disturbances resulting from climate change. According to the workshop report, the research measures suggested should improve understanding of the greenhouse effect and develop response options to keep the risks associated with climatic change within acceptable bounds.

The report presented the position that there are many long-term actions that will be required in order to ensure appropriate responses to climate change. Among the immediate steps the workshops suggested was the need for governments to take immediate action to reexamine their long-term energy strategies with the goals of achieving high end-use efficiency, reducing multiple forms of air pollution and reducing CO_2 emissions. It further noted that research and development relevant to these issues, in particular the development of alternative non-fossil energy

systems, must be greatly intensified. In regard to achieving CO_2 reductions in spite of continued population growth and economic expansion, the Villach and Bellagio workshops concluded that governments should give the following long-term objectives high priority: (1) increasing energy operation and transmission efficiencies and reducing energy demand and increasing the application of available technologies; (2) replacing fossil fuel combustion with electricity generated from alternative energy such as solar, wind, hydroelectric, nuclear, and ocean thermal which possibly could be stored and transported by using hydrogen gas as a carrier; (3) reviewing reforestation and encouraging reforestation, which can provide a system for reducing atmospheric increases in CO_2 and the other trace gases; (4) shifting fossil fuel use from high CO_2 emitting fuels like coal, to low ones such as natural gas; and (5) disposing of CO_2 captured from power plant flue gas in the deep ocean; like current pollution control requirements in several countries, such disposal would double the cost of producing electricity for 90 percent CO_2 removal.

The workshop's report also noted that measures should be undertaken to limit emissions of non-CO_2 greenhouse gases and to avoid industrial and societal actions that contribute to their atmospheric concentrations. To reduce methane emissions, the workshop recommended: the further development of technologies to utilize methane from solid waste landfills for energy production; the attention of agricultural practices that produce methane; and the control of NO_x and hydrocarbon emissions from fossil fuel combustion, which are linked to ozone and methane production. For the limitation of NO_x emissions, combustion controls and modification of the type and method of fertilizer application were recommended. With regard to the reduction and eventual elimination of CFC emissions, the workshops also supported efforts to protect the ozone layer.

In addition to greenhouse-gas reduction measures, climate change adaption measures were also advanced. The adaption measures include changes in agricultural practices at the farm level, like the greater use of the thermal and moisture stress-resistant plant varieties and investments to promote water-use efficiency. Measures to adapt agricultural and other practices to sea-level rises accompanying the probable global warming were also stressed by the workshop's climate experts. Increased attention should be paid to the monitoring of worldwide sea-level changes so that areas vulnerable to sea-level rise can be identified, and river, estuarine, and coastal zone policies like coastal installation and land-use planning, can be implemented.

American Nuclear Energy Council

Edward M. Davis, President of the American Nuclear Energy Council testified on August 11, 1988, before the Senate Committee on Energy and Natural Resources on the importance of nuclear energy in any national energy policy that takes into account climate modification concerns. Mr. Davis believes nuclear energy, which generates no CO_2, can help limit global warming by meeting the nation's demand for electricity, which has grown an average of 3.3 percent a year since 1982. But, in order to increase nuclear's future utilization, Davis recommends governmental action to reduce its costs and improve its safety. To reduce the costs of licensing plants, Davis feels the Congress should enact legislation providing for standardized, pre-approved plant designs and establishing a one-step plant licensing process. To improve nuclear's safety record, Davis wants to implement the National Waste Policy Act of 1982, a law that would apply available technologies in nuclear waste disposal. He also supports DOE funding of advanced reactor technologies like advanced light-water, liquid-metal, and high-temperature, gas-cooled reactors that incorporate passive safety features into their designs.

National Academy of Engineering

Another non-governmental expert, Robert M. White, President of the National Academy of Engineering, testified on February 21, 1989, before the Subcommittee on Energy and Power of the Committee on Energy and Commerce on the federal government's role in averting climate change. He urged the government to take prudent actions that would weigh the consequences of global warming against the uncertainty of our knowledge about atmosphere and greenhouse gases. Such government action suggested by Dr. White included both research and emissions-reduction measures. Government measures to reduce greenhouse-gas emissions such as increasing the efficiency of fossil-fuel use, switching to non-fossil and low CO_2 emitting fossil energy sources, and limiting CFC use and tropical deforestation were advocated by Dr. White.

Clean Energy Institute, University of Miami

Dr. T. Nejat Veziroglu, Director of the Clean Energy Research Institute at the University of Miami, has promoted the use of hydrogen to replace fossil fuels. He testified before the Subcommittee on Natural Resources, Agriculture Research and Environment and the Subcommittee on Science, Research and Technology on June 29, 1988, and reported that in an era of increasing concerns about climate modification, the hydrogen option is attractive: hydrogen can be produced from water, an inexhaustible resource, at a cost that is low compared to that of other synthetic fuels. Hydrogen also is the least polluting of all the synthetic fuels since it does not produce CO_2. Hydrogen's properties enables it to be

applied in a number of the economy's sectors. Because hydrogen is storable and a very efficient energy carrier, it can be transmitted efficiently underground through pipelines to provide heating and cooling for industry, buildings, and homes. According to Dr. Veziroglu, hydrogen with its high flame speed and wide flammability limits, can additionally fuel internal combustion engines, gas turbines, and jet engines. Perhaps most importantly, hydrogen's high ignition temperature and low flame luminosity make it a safer and 15 to 20 percent more efficient fuel in converting chemical to mechanical energy. A barrier to hydrogen's increased application is its cost, relative to that of fossil fuels. After accounting for both hydrogen's 26 percent greater efficiency on a weighted average basis and its transportation and distribution costs, the liquid hydrogen, having an energy yield equivalent to one gallon of gasoline, costs $1.94 per gallon as compared to $1.00 per gallon of gasoline. However, as Dr. Veziroglu pointed out, liquid hydrogen becomes cheaper than gasoline if the price of gasoline is raised by $1.00 per gallon in order to account for the environmental damage that results from its use.

American Council for an Energy-Efficient Economy

The American Council for an Energy-Efficient Economy is a nonprofit organization dedicated to the advancement of energy-conserving technologies and programs. In 1988, it published "Energy Efficiency: A New Agenda." Policy proposals and comments for this publication were contributed by many representatives from various organizations including the International Institute for Energy Conservation, the Advanced Study Program of the National Center for Atmospheric Research, and the World Resources Institute.

The Council's report stressed the superiority of energy efficiency over other energy options, explaining that it reduces the risk of future global climate change, strengthens U.S. energy security by diminishing oil imports, and enhances the competitiveness of U.S. industry by reducing its production costs. The report proposed technically feasible policies that it hoped the President would implement to create an energy-efficient economy, with the ultimate goal of a reduction in U.S. energy intensity (the rate of energy used per dollar of economic output) by at least 2.5 percent per year into the 21st century. The following measures are among the suggestions offered to achieve these reductions

- apply energy-efficiency measures to protect the national and global environment,
- double car and light-truck fuel economy to cut oil imports,
- enhance industrial competitiveness with energy-efficiency research,

- make buildings more efficient to improve their affordability, and
- help developing nations acquire skills and technology for energy efficiency.

According to the report, the U.S. can advance energy-efficiency measures to reduce the risk of climatic change. On the international level, the U.S. can promote global energy efficiency through technical exchanges and through a protocol to reduce the energy intensity of the global economy. Domestically, it advocated the coordination of state and federal energy and environmental planning. It also encouraged the development of technologies which could reduce or eliminate CFC use and increase efficiency in energy-related applications. It stated that DOE and EPA should undertake an urgent research, development, and demonstration program to support promising, albeit financially risky, technologies that the private sector will not support on its own.

To double car and light-truck fuel economy, the report proposed the implementation of both regulations and taxes. First, the report suggested that, by the year 2000, car and light-truck fuel economy standards be raised to 45 and 35 miles per gallon, respectively. It also proposed raising gasoline and diesel fuel taxes by 10 cents per gallon per year for at least 3 consecutive years, to a maximum tax of 30 to 50 cents per gallon, depending on world oil prices. Such a tax would require fuel consumers to pay the environmental and national security costs of importing and using oil. To solve the political problem of implementing a tax adversely affecting low income people who spend a disproportionate fraction of their income on gasoline, the report suggests rebating a portion of the tax. It also proposed the establishment of a "gas-guzzler" tax for inefficient cars and trucks and a $1,000 per car "gas-sipper" rebate paid from the guzzler tax revenues to purchases of low-polluting vehicles that meet a fuel economy level which is, for example, 50 percent higher than that of today's most efficient models. This tax rebate program would discourage the production of very inefficient cars and trucks and encourage the production of highly efficient vehicles. The fuels tax and fuel economy standards only discourage such production indirectly.

To enhance U.S. industrial competitiveness, the report strongly supported increased, long-term federal commitment to the development and demonstration of new energy-efficient technologies. Such federal work, which could reduce American manufacturers' $100 billion-plus annual energy bill, is necessary since U.S. companies significantly underinvest in research, due to uncertainties and delays in its payback.

The Council's report stated that the funding for DOE conservation research and development, which has been slashed by more than 50 percent, should be raised since in the past it developed and established the market viability of projects that will yield billions of dollars in energy savings. For instance, both electronic ballasts for fluorescent lamps, which cut electricity use by about 25 percent, and low-emissivity windows, which account for more than half of the largest U.S. window maker's sales, were supported by the DOE program. Additional research can be conducted in research centers for improving energy-intensive industrial processes like the refining and processing of steel scrap. The lead agency for these centers—whose research should not be confined to applications of newly discovered scientific phenomena like lasers, bioengineering, or superconductivity—could be DOE or NSF, although there should be government-wide technical cooperation. In improving U.S. industrial competitiveness, the council also advocated the government's establishing a coordination program to monitor and distribute information on foreign energy-efficiency research and technical development, so that the technological needs of domestic firms, necessary federal research investments, and the export potential for U.S.-made energy-efficiency products and process technologies can be identified.

To improve the affordability of buildings, the council suggests raising their efficiencies, so that their energy costs are reduced by 30 to 50 percent. According to the report, the government could improve the effectiveness of and increase funding for low-income weatherization; especially for multi-family buildings. For federal office buildings, it suggested that conservation investment guidelines and new aggressive energy conservation goals be established, such as 25 percent energy savings per square foot of floor space within 10 years. It also suggested that federal officials be prompted to employ energy-saving technologies by allowing them to retain part of their energy savings to meet agency budgetary needs. With regard to non-federal buildings, it advocated the establishment of federal minimum efficiency standards for fluorescent and incandescent lamps. By the year 2000, such standards could annually reduce electricity consumption by 25 billion kWh and save consumers approximately $1.9 billion.

The Council's report also noted the U.S. government can help—directly, through its agencies, and indirectly, through the development institutions it financially supports—developing nations acquire the skills and technology to make their use of energy more efficient. Directly through its Agency for International Development and other agencies, it can arrange for experts from universities and the private sector to support

development of efficient fossil fuel- or biofuel-based technologies, technical and program data bases, and information exchange in the Third World. Through its Export-Import Bank and Trade and Development Program, the government can help developing nations acquire energy-efficient skills and technology by financially supporting domestic firms' marketing and by establishing joint technology ventures in those countries. According to the report, the U.S. government should convince multilateral lending and development institutions like the World Bank, which provide much of the funding and technical assistance for Third World energy projects, to support least-cost conservation. Since the U.S. is a major donor to these multilateral institutions, it could advocate a fundamental reorientation in their energy planning and lending policies that may benefit this country. The U.S. may gain new export markets for environmentally beneficial, energy-efficient technologies. As developing nations use this technology, their economic productivity and amount of free foreign exchange can rise, which may in turn enable them to increase their imports of U.S. goods.

Environmental Defense Fund

Dr. Daniel J. Dudek, Senior Economist for the Environmental Defense Fund, on September 19, 1988, in testimony before the Senate Committee on Energy and Natural Resources, provided his views on how the U.S. Government should respond to global warming concerns. To arrest the rapid growth of atmospheric CO_2 emissions that could result from decreased real energy prices and future increased utilization, and which would be responsible in part for any global warming, Dudek would require all new CO_2 sources to find compensating CO_2 emissions reductions elsewhere. CO_2 offsets, which could spur new energy-efficiency developments, could be feasibly applied to the stationary sources that account for 70 percent of total CO_2 emissions in the U.S. The federal government could identify and evaluate alternative offset opportunities, which could make the construction of new expensive power generating capacity unnecessary. Such opportunities include CO_2 scrubbing and disposal from power plant stack gases, and conservation measures like planting shade trees around homes to reduce energy demand. However, these offsets are relatively expensive. Planting shade trees in residential areas is estimated to cost between $1.49 to $7.43 per metric ton of CO_2 prevented, while removing 90 percent of the CO_2 from a modern coal-fired 200 megawatt plant's stacks would increase its electric generating costs by 3 to 6 times, depending upon the CO_2 disposal option used. Investments could also be made in mass transit options to reduce mobile sources of CO_2, but they, too, are likely to be expensive.

Due to the high costs of the aforementioned options, Dr. Dudek advocated the widespread planting of trees as a modestly costing offset for CO_2 emissions. Planting can also lead to the reduction of erosion and surplus agricultural production, to the generation of energy from biomass, and to the production of timber goods.

In addition to the environmental benefits accrued from tying global warming-instigated afforestation, Dr. Dudek also noted that with proper management, trees could be cultivated plantation-style, so that their wood could be used for furniture and pulpwood production, or for electricity generation through biomass combustion.

Fusion Energy Option

Erik Storm, Deputy Associate Director, Inertial Confinement Fusion Program at the Lawrence Livermore National Laboratory, advocated the use of fusion energy in his June 29, 1988, testimony before the House Subcommittee on Natural Resources, Agriculture Research and Environment, and the House Subcommittee on Science, Research, and Technology. Fusion occurs when the nuclei of lighter hydrogen atoms are combined, i.e., under high temperatures and pressures, into a single heavier helium nucleus. Some of the original nuclei mass is converted into energy.

Erik Storm advocated fusion since he felt it was the only advanced energy option that had the potential to provide an environmentally attractive, safe, and virtually inexhaustible energy source. Such a source would be needed to meet global energy demand that will rise as the world population increases and the Third World industrializes. As fusion is powered with deuterium—which can be extracted from ordinary water for pennies per gallon—and with tritium—which can be derived from lithium supplies that are expected to last for more than 10,000 years—it can replace the greenhouse gas-emitting combustion of limited fossil fuel resources, according to Storm. Fusion, which could offer the ideal of high density power production, would also be a safe energy option with regard to radioactive waste and emissions concerns. The tritium used in fusion reactors has a radioactive half-life of only 12-1/2 years compared to the longer ones of fission fuel and fission by-products. Meltdowns are not possible with a fusion reactor, according to Storm, because only a small amount of fuel is present at one time, and because it is not a self-sustaining reaction. As an additional safeguard against emissions of radioactive materials, a fusion power plant can be designed so that even if the plant were demolished, the environmental exposure at the site would be well below today's industrial standards.

Dr. Storm noted that with a national commitment it is possible that commercial fusion power could be a reality early in the 21st century because the scientific feasibility of fusion energy is now certain—a claim that could not be made 5 years ago. Dr. Storm believes that a national policy to support long-term fusion energy research and development will help ensure implementing fusion technology for commercial power.

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